

AD-A083 000

NAVAL OCEAN SYSTEMS CENTER SAN DIEGO CA
LIFE CYCLE COST ESTIMATES OF THE AM/HLR-10, AM/ELG-32(V)E, AND --ETC(U)
SEP 79 E. L. WELKER, J. VALENZUELA

F/S 17/0

UNCLASSIFIED NOSC/TR-000

ML

For J
40
ACR300N

NOSC

END
DATE
FILMED
5-80
DTIC

12 LEVEL

NOSC

NOSC TR 500

NOSC TR 500

Technical Report 500

LIFE CYCLE COST ESTIMATES OF THE AN/WLR-1G, AN/SLQ-32(V)2, and CONCEPTUAL ESM SYSTEM

EL Welker and J Valenzuela,
Evaluation Research Corp.
Monitored by DH Marx,
NOSC

September 1979

Approved for public release; distribution unlimited

NAVAL OCEAN SYSTEMS CENTER
SAN DIEGO, CALIFORNIA 92152

A

DTIC
SELECTE
APR 14 1980

80 4 14 033

ADA 083008

JDC FILE COPY



NAVAL OCEAN SYSTEMS CENTER, SAN DIEGO, CA 92152

AN ACTIVITY OF THE NAVAL MATERIAL COMMAND

SL GUILLE, CAPT, USN

Commander

HL BLOOD

Technical Director

ADMINISTRATIVE INFORMATION

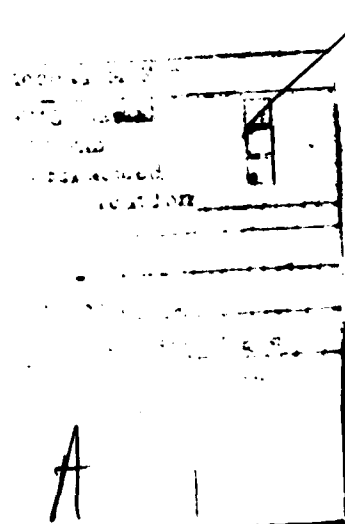
The work reported herein was sponsored by the Naval Material Command under subproject ZF-12-113-001, program element 62712N (NOSC project SS21). This work was performed over the period June– September 1979 by Evaluation Research Corporation, West Coast Division, under contract N66001-78-R-0318 with the Naval Ocean Systems Center.

Released by
R. L. Petty, Head
Sensor Processing and
Analysis Division

Under authority of
R. E. Shutters, Head
Surface/Aerospace
Surveillance Department

CONTENTS

1.0 EXECUTIVE SUMMARY . . .	page 5
2.0 INTRODUCTION . . .	7
2.1 Description of the Three ESM System Configurations . . .	7
2.1.1 AN/WLR-1G System Description . . .	7
2.1.2 AN/SLQ-32(V)2 Description . . .	7
2.1.3 The Conceptual ESM Design Description . . .	7
2.1.4 Operating and Maintenance Consideration . . .	8
2.2 The Concept and Rationale of Life Cycle Cost . . .	8
2.2.1 Acquisition Costs . . .	9
2.2.2 Operating Costs . . .	10
2.2.3 Maintenance Costs . . .	10
2.2.4 Salvage Value and Termination Costs . . .	11
3.0 LCC COMPUTATIONS . . .	11
3.1 Basic Formulas Used in LCC Computations . . .	11
3.2 The Sources and Rationale for the Input Cost, Failure, and Maintenance Data . . .	12
3.2.1 AN/SLQ-32(V)2 Shipboard Repair Parts Cost Estimate . . .	12
3.2.2 AN/SLQ-32(V)2 R&D Cost Estimate . . .	13
3.2.3 AN/SLQ-32(V)2 Depot Support Repair Cost Estimate . . .	13
3.2.4 Conceptual ESM Depot Repair Cost Estimate . . .	14
3.2.5 AN/WLR-1G and AN/SLQ-32(V)2 Tools and Test Equipment Cost Estimate . . .	14
3.2.6 Summary of Data Inputs and Numerical Estimates of LCC Elements . . .	14
4.0 DISCUSSION OF RESULTS . . .	19
4.1 Discussion of LCC Categories . . .	19
4.1.1 Research and Development Costs . . .	19
4.1.2 Procurement Cost . . .	19
4.1.3 Initial Spares Cost . . .	19
4.1.4 Tools and Test Equipment . . .	19
4.1.5 Operating and Maintenance Cost . . .	19
5.0 RECOMMENDATIONS . . .	22
6.0 REFERENCES . . .	23



TABLES

3-1	AN/WLR-1G Special-Purpose Test Equipment List . . .	page 15
3-2	AN/SLQ-32(V)2 Special Test Equipment Cost . . .	16
3-3	Basic Cost, Failure, Repair and Operational Data . . .	17
4-1	Summary of Life Cycle Costs Per System for Three ESM Configurations . . .	20

ABBREVIATIONS

ASW	Antisubmarine warfare
BITE	Built-in test equipment
ECM	Electronic countermeasures
ESM	Electronic support measures
LCC	Life cycle cost
LORA	Level of repair analysis
MIC	Microwave integrated circuit
MTBF	Mean time before failure
MTBMA	Mean time between maintenance actions
MTTR	Mean time to repair
OPEVAL	Operational evaluation
TECHEVAL	Technical evaluation

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM	
1. REPORT NUMBER NOSC/TR-560	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle) Life Cycle Cost Estimates of the AN/WLR-1G, AN/SLQ-32(V)2, and Conceptual ESM System		5. TYPE OF REPORT & PERIOD COVERED Research and development Sept. June - September 1979	
7. AUTHOR(s) EL Welker and J Valenzuela, Evaluation Research Corp		8. CONTRACT OR GRANT NUMBER(s) 12/251	
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Ocean Systems Center, San Diego CA 92152		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS ZF12-113-001, 62712N	
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Material Command, Washington DC		12. REPORT DATE September 1979	
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) E. L. Welker J. Valenzuela		13. NUMBER OF PAGES 23	
		15. SECURITY CLASS. (of this report) Unclassified	
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE	
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution unlimited 16 F-1131 17 ZF12113971			
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)			
18. SUPPLEMENTARY NOTES			
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) Electronic Support Measures Reliability ESM Maintainability Electronic Warfare Life cycle cost Availability			
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) A life cycle cost estimate is made for each of three shipboard ESM systems. One is an older equipment, the AW/WLR-1 and its ancillary items. The second is the currently evolving AN/SLQ-32. A newly conceived NOSC architecture is the basis for the third system. Material is presented that augments the cost data with the conditions under which it applies.			

DD FORM 1 JAN 73 1473

EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-LF-014-6601

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

393 127

JP 12

1.0 EXECUTIVE SUMMARY

This report presents the life cycle cost (LCC) analyses of three electronic support measures (ESM) configurations. The first is of the AN/WLR-1G, which is based on electron tube technology and has been in use for about 20 years by the Navy. The second is of the AN/SLQ-32(V)2, which is based on solid state technology and is now being phased into Fleet use. The third is of a conceptual design that is visualized as a next-generation system to follow the AN/SLQ-32(V)2. This report presents the basic concepts and rationale of LCC analysis. It describes the nature and sources of the input data on system failure, repair, cost, and operational characteristics for each of the three ESM system designs. The cost model was selected to be as simple as possible while still reflecting those cost elements that are sensitive to the design of an ESM system. These cost elements are divided into two groups: (1) the elements which determine system acquisition cost, research and development, procurement or production, initial spares, and the shipboard tools and test equipment; (2) the operating and maintenance costs which accrue over the service life, including expenses for the system's operator and the equipment's maintenance, both labor and material. The term "maintenance" refers to both preventive and corrective actions, the latter including organizational and intermediate levels on shipboard and in depots on shore.

The overall LCC analysis summary is shown and discussed in Section 4.0. For convenience, the summary table presented in that section is reproduced here. Costs are indicated on a per-system basis. The three configurations differ only slightly in their life cycle costs due to operation and maintenance, but they differ significantly with respect to acquisition cost. The AN/SLQ-32(V)2 cost for research and development (R&D) is high because two parallel R&D efforts were funded. The high procurement cost for the conceptual configuration reflects the ever-increasing costs for microwave components plus the expense of added performance capability and flexibility. The emphasis on shipboard maintenance for the conceptual system coupled with a module discard policy leads to a higher cost for the initial spares. The comparison of the cost elements in table 4-1 is amplified in the text of the report.

Four recommendations are presented:

1. A centralized DoD or Navy LCC data base should be generated from user and other experience to allow timely and accurate LCC comparisons between proposed and existing systems. Such data are now fragmented or nonexistent.
2. Alternative maintenance philosophies should be considered for possible LCC reductions of the conceptual system. Approaches such as shipboard module repair and elimination or reduction of throw-away modules are examples.
3. Design alternatives should be identified and evaluated in terms of performance and cost trade-offs to determine the limiting factors involved in a conceptual ESM system development program.
4. Development efforts for the conceptual ESM should include an appraisal of the amount of microwave integrated circuitry (MIC) that can be achieved within the current state-of-the-art and its potential for cost savings. The MIC proposed here embodies the integration of several functions into a single package.

Summary of life cycle costs per system for three ESM configurations.
(Cost in thousands of 1979 dollars)

Acquisition Costs Prorated for a Production of 100	AN/WLR-1G		Per System Costs & % AN/SLQ-32(V) 2		Conceptual	
	Cost	%	Costs	%	Costs	%
1. Research and Development	30*	.543	411	19.125	36	1.234
2. Procurement	220.	19.910	799	37.180	1,406	48.2
3. Initial Spares	22.	1.991	80	3.723	593	20.33
4. Tools and Test Equipment	73	6.606	25	1.163	25	.857
5. Total Acquisition Costs (sum of lines 1 through 4)	345	29.050	1,315	61.191	2,060	70.621
6. Operator Personnel	512	46.335	527	24.523	530	18.169
7. Corrective Maintenance Labor	24	2.172	24	1.117	30	1.028
8. Corrective Maintenance Material	237	21.448	266	12.378	286	9.805
9. Total Corrective Maintenance (sum of lines 7 and 8)	261	23.620	290	13.495	316	10.833
10. Preventive Maintenance	11	.995	17	0.791	11	.377
11. Total Maintenance (sum of lines 9 and 10)	272	24.615	307	14.286	327	11.21
12. Total Operating and Maintenance Costs (sum of lines 6 and 11)	784	70.950	834	38.809	857	29.379
13. Total 10-Year LCC (sum of lines 5 and 12)	1,129	100.00	2,149	100.00	2,917	100.00

* Data not available. Estimate based on past experience.

2.0 INTRODUCTION

A continually increasing development of highly sophisticated electronic weapons systems has led to greater interest in more sophisticated ESM equipment. This report is part of an overall ESM improvement study targeted at achieving improved operational availability and dependability in the ESM systems of the future. It deals with the economic aspects of ESM equipment expressed in terms of system LCC, which is the total cost of ownership over the planned service life of the equipment.

The Naval Ocean Systems Center has been interested in comparing the LCC of three ESM designs. These are designated AN/WLR-1G, AN/SLQ-32(V)2, and an undeveloped conceptual configuration. This report presents the results of the LCC analysis of each of the three architectures. The approach used resulted in an evaluation that highlighted cost elements sensitive to the individual hardware designs and their operating and maintenance characteristics.

2.1 DESCRIPTION OF THE THREE ESM SYSTEM CONFIGURATIONS

2.1.1 AN/WLR-1G System Description

The AN/WLR-1G receiving set consists of a number of units containing RF tuners, frequency converters, RF switches, power supplies, and a pulse analyzer. When coupled with the AS-899/SLR and other antennas, the AM-1017B Magnetic Control Amplifier, the C-3118 Control Indicator, and the AN/WLA-3B Amplifier, a complete ESM receiving system is formed. This is the surveillance system currently being used in the Fleet and is based on electron tube technology.

The AN/WLR-1G equipment is distributed in three locations when installed aboard ships. The tuners, power supplies, and RF switches are usually installed in an ESM equipment room. The antennas are mast mounted, either forward or aft, depending on the ship's configuration. The frequency converters, pulse analyzers, and various control units are located in the operators' area in the Combat Information Center (CIC).

2.1.2 AN/SLQ-32(V)2 Description

The AN/SLQ-32(V)2 is currently in the early operational phase, and therefore much of the information used in this report is based on engineering estimates and the characteristics reported in the system's technical manuals. It is a passive ESM system providing automatic threat acquisition identification and display. The system design is based on solid state technology.

The system hardware and its operations are briefly described as follows: Signals are received via a fixed antenna subsystem. The antenna subsystem is divided into four multi-beam antenna arrays and two semiomnidirectional antennas to cover bands 2 and 3. Four spiral antennas are used for band 1. Frequency coverage is classified information and may be found in Ref. 4.

2.1.3 The Conceptual ESM Design Description

The conceptual ESM system is visualized as a next-generation design following the AN/SLQ-32(V)2. It is a four-channel down converter that possesses many shared signal

processing assets and has a multiple demodulation capability. Signals received are processed by various receivers, and a computer subsystem enables rapid parameter measurement, classification, identification, and bearing determination. Superheterodyne receivers fed from the down converter allow long-range intercept (beyond-the-horizon surveillance). The four-channel down converter configuration utilizes special frequency and DF measurements at baseband to obtain threat warning reception (line-of-sight surveillance) together with bearing determination.

The equipment has been divided into two main groups, exterior and interior. The exterior group is the four-channel down converter section mounted on the mast. The interior group is the IF receiver and signal processing portion of the equipment located below decks. It includes a control and display console and would most probably be in the CIC.

Detailed design drawings for the conceptual configuration do not exist. For purposes of this ESM study, it was necessary to prepare basic functional diagrams and to postulate what hardware elements would be required in the system when it is finally designed. The functional diagrams and hardware element lists were prepared in sufficient detail to support the estimation of reliability, maintainability, and cost parameters required for the LCC analysis.

The design concept was used as a basis in developing a compatible maintenance philosophy. The key elements in this maintenance philosophy are repair vs discard rules and the level at which maintenance is to be performed (organizational, intermediate, or depot). These rules must be specified for each type of failure.

2.1.4 Operating and Maintenance Consideration

The planned duty cycle for the ESM system is as follows. Each mission is to last 30 days, with the equipment operating continuously. This gives the system a mission length of 720 hours. It is also assumed that each ship will perform six missions per year. With an anticipated service life of 10 years, each ESM suite will be operated for 60 missions.

For each of the ESM configurations, the Navy desires continuous watch by an operator trained to perform preventive and unscheduled maintenance. It is Navy policy that a watch should not exceed 4 hours. Typically each operator is scheduled for two watches per day; therefore three operators are required for each of the ESM configurations. Since the Navy wishes to have an ESM operator on duty continuously, there is no requirement for completely automatic operation.

For the conceptual ESM system, shipboard maintenance will be performed at two levels. Organizational maintenance will be done at the site of the failure and intermediate maintenance in the shipboard repair facility. Depot maintenance is performed for failures for which shipboard repair is not feasible.

2.2 THE CONCEPT AND RATIONALE OF LIFE CYCLE COST

The true cost of a system is not limited to its initial purchase price or acquisition cost. Rather, it is the total cost of ownership of the system, which includes the initial purchase price, the operation and maintenance costs, and the salvage value at the end of the service life of the system. This total cost of ownership is commonly referred to as life cycle cost (LCC). At first glance, it might appear that the LCC of a system is quite easily

determined once the system has been defined, but such is not the case. The cost of ownership depends on the quantities of the system procured (higher quantities help amortize R&D costs), the maintenance philosophy, and other factors.

The estimation of an LCC is also influenced by the detail desired by management and by the nature of the available input data. For example, consider any shipboard military system. Perhaps at the lowest level, one considers only the acquisition cost of the system hardware, its documentation, and the costs incurred in operating and maintaining it over the planned service life. Advancing to a higher level, one would include shipboard operation and maintenance facilities and shore depot facilities, training, training aids, documentation control, etc. At an even higher level, an LCC analysis could include costs of military support and administration, even up to the level of expenditures at Navy Headquarters.

There are two basic reasons for choosing the level for an LCC analysis. One is to properly budget the overall cost of ownership of the system. The other is to compare costs among competing alternatives. In the present ESM study, we are concerned with the second objective. This is most effectively accomplished by using an LCC model that includes those cost elements that are sensitive to hardware design, equipment operation, and the maintenance characteristics of the alternative system configurations. The following sections identify the specific factors included in the ESM LCC model.

2.2.1 Acquisition Costs

Generally, acquisition costs include the initial outlay for the procurement of the number of ESM systems required in the operational fleet. The Navy might elect to purchase a few additional complete systems, which would be identified as complete system spares for training, evaluation of proposed engineering changes, and configuration control. These could be included in the cost model as separate items when an attempt is made to determine actual LCC rather than comparative LCC. A portion of the procurement price of the hardware reflects the R&D costs, and the remaining portion reflects the production costs.

For proposed hardware still in the conceptual stage, it is customary to include both the R&D and production cost elements in the LCC model. The separation of the two is useful because R&D costs are independent of the size of the production run, whereas production costs are not.

An initial complement of spares is also a part of the system acquisition, and it is appropriately costed under this classification. This refers to spares at all indenture levels, from spare parts up to the complete spare systems mentioned above. The number of initial spares for this task was determined on the basis of information about failure frequency, cost, acceptable risk of stock-out, and the maintenance philosophy.

In addition to the operating hardware and spares, the acquisition cost includes pricing for special tools and test equipment appropriate to each ESM design alternative. These costs are computed for operating systems on shipboard and for depot maintenance. In this connection, one should also consider the expense of shop space, shipboard and depot, and the space occupied by the operating equipment on board ship. For the ESM LCC analysis, it was decided not to include a costing of space allocated to maintenance and the operating ESM system. There are two reasons for this exclusion. In the first place, it is believed that the alternative ESM configurations probably do not critically differ in space requirements. Secondly, for typical Navy ships, the space for ESM equipment already exists, no matter

which configuration is selected. The exclusion of space costs can be reviewed when the system descriptions and cost estimates are completed. If desired, space costs can be easily added to the model.

There are a number of other one-time cost elements that occur during the acquisition of a system. These include system documentation, the preparation of operating and maintenance manuals, the development of training programs, and the installation, testing, and check-out of operational systems. Although these items can be very costly, it is believed that they are not sensitive to the ESM system configuration, and these costs are not included in the ESM LCC analysis. This exclusion is prompted by the following considerations. ESM system number one (AN/WLR-1G) is already installed and has been in use for some time; yet accurate data concerning one-time costs for system documentation, training, and technical check-out are not available. Systems two and three each involve more current technology and rely on built-in test equipment (BITE) to identify system malfunctions. Thus, it is expected that systems two and three will not differ significantly with respect to operational and maintenance procedures and manuals, training of operating and maintenance personnel, and testing and check-out costs.

2.2.2 Operating Costs

These costs include the costs of the crew, the staff, the material, security, and any other deployed manpower, including support personnel. All of these are shipboard costs, and the personnel involved are necessarily on board and available all of the time. Personnel requirements will be costed in the LCC model. Spares required in maintenance actions will be discussed later. Other material and consumables will be costed as appropriate.

2.2.3 Maintenance Costs

There are two categories of maintenance that contribute to the total cost of maintaining the system. One relates to the periodic preventive maintenance actions, which are intended to reduce the failure rate during the operation of the ESM system. The other category is called corrective maintenance. Corrective maintenance actions are initiated by a failure within the system, and the maintenance action is intended to restore the failed element of the system to its former operable state. For an electronic system like the ESM, it is postulated that preventive maintenance actions will consist almost exclusively of cleaning and adjustments, with no replacement of parts. The cost of the preventive maintenance of the ESM system is shown in the LCC analysis.

Corrective maintenance costing is divided into two analysis elements: labor and failure distribution. Studies of these elements yield an average or mean time to repair (MTTR) for each of the three maintenance levels: organizational, intermediate, and depot. Standard Navy labor rates are used to estimate the expense of these corrective maintenance hours. Failure frequency by type of failure is computed from the failure rates generated in the reliability analysis and the mission operating time. Part failure rates, rather than the mission failure rates used in the availability calculations, are also used to generate spare material costs. Materials costs incurred in corrective maintenance actions are determined for each failure type, appropriately reflecting the repair or discard maintenance philosophy for the part involved.

The cost of replenishment spares is usually included as a separate element in the LCC analysis. However, in this ESM analysis, the cost of replenishment spares is included in the

cost of corrective maintenance as either a replacement or repair expense, whichever applies. This costing procedure implies that hardware drawn from spares is always replaced, so that the supply of spares is always maintained at the level of the initial spares procurement.

2.2.4 Salvage Value and Termination Costs

At the end of the service life of the ESM, the system hardware must be removed from ships and depots, presumably to be replaced by newer configurations. The removal process must be included as an element in the LCC. The salvage value of the removed hardware is included as a credit against the other termination costs. In the ESM LCC analysis, it is assumed that removal costs are equal to salvage value, and therefore no entry is shown for this cost element.

3.0 LCC COMPUTATIONS

3.1 BASIC FORMULAS USED IN LCC COMPUTATIONS

Each system or system subunit is credited with one mean life (MTBF) of operating time between maintenance actions. It is assumed that maintenance is initiated immediately after failure, so that the MTBF equals the mean number of hours between maintenance actions (MTBMA). Therefore in a mission of 720 hours, the average number of failures is obtained by dividing (720 minus down time) by the appropriate MTBF. Similarly, it is assumed that each repair is completed in the average or mean time to repair (MTTR). A single MTTR value, unique to each ESM configuration, is used for each repair level, organizational, intermediate, and depot. A labor rate of \$12.68 per hour is used for preventive maintenance and for corrective maintenance at the organizational and intermediate levels. The rate for depot maintenance labor is \$28.55 per hour. Preventive maintenance requires 0.5 hours per day for the AN/WLR-1G and the conceptual design and 0.75 hours per day for the AN/SLQ-32. The preventive maintenance labor cost for a 30-day mission is $(0.5)(30)(\$12.68) = \190.20 for the AN/WLR-1G and the conceptual design and $(0.75)(30)(\$12.68) = \285.30 for the AN/SLQ-32.

The labor hours for corrective maintenance at each level are computed in accordance with a defined repair philosophy. The repair philosophy establishes which types of subunit failures are repaired at each level. In some cases this is based on the type of subunit causing the failure, and in other cases it is a percentage of the number of potential failures. The number of failures of each type during a mission is computed as the product of the appropriate failure rate and the mission length, 720 hours.

Next, the repair time associated with the failures is established. The associated repair time is the product of the number of failures and the applicable MTTR. This figure is then multiplied by the repair labor rate to obtain the resulting corrective maintenance labor cost. In this computation, the type of failure refers to the level at which the repair is performed and not to the subunit involved. The associated failure rate for each repair level is computed by adding the failure rates of the subunits repaired at each level.

Material costs are computed separately from labor expenses. First, data are assembled which show the cost of materials for the repair of each specified system hardware subunit; these data are then correlated with the subunit failure rate. The failure rate of a subunit is then

used to compute the expected or average number of failures of the subunit in a 720-hour mission. Finally, the product of the material costs per repair and the number of failures of a subunit per mission is computed for each subunit. The sum of these products gives an estimate of the total cost of materials for corrective maintenance per mission. When this total is divided by the average number of failures per mission, the average cost of materials per repair for the configuration is obtained.

The number of operator hours during a mission is obtained by subtracting the total number of shipboard preventive and corrective maintenance hours from the number of man-hours available during a mission. Corrective maintenance man-hours are added to operator hours for each of the three configurations on the basis of the respective failure rates and MTTRs of each system. Preventive maintenance is presumed to be performed by the operator. The net effect of this reasoning is a requirement for three men to serve two 4-hour watches during each 24 hours. Some of this time is spent operating the equipment, while the remaining time is used for preventive and corrective maintenance.

As stated, it was assumed that each system would be tasked to perform six missions per year. Thus, in a 10-year service life, each system would perform 60 missions. Further, as described above, labor and materials costs were computed on a per-mission basis. These per-mission costs were then multiplied by 60 to obtain the costs over the 10-year service life.

3.2 THE SOURCES AND RATIONALE FOR THE INPUT COST, FAILURE, AND MAINTENANCE DATA

Failure rates for assemblies and systems for all configurations were obtained from reliability prediction analyses. Mean repair times (MTTRs) for organizational and intermediate maintenance levels were obtained from maintainability studies and past experience with similar electronic systems. The MTTR estimate for depot maintenance was obtained from Table 7-21 of "Average Corrective Maintenance Time Experience for Electronic Equipment," the Naval Material Command's general costing guide. This document lists maintenance times for wired-in parts. Navy labor rates were obtained from Table 4-3, "GEE Model Factors."

The rate for organizational and intermediate labor on aircraft carriers was selected for shipboard organizational and intermediate-level maintenance. The depot labor rate shown in this table was used for ESM depot maintenance. The tabular rates were inflated at the rate of 10% per year to transform them into 1979 dollars.

The following paragraphs provide in summary form the development of a number of other data items used in the LCC analysis.

3.2.1 AN/SLQ-32(V)2 Shipboard Repair Parts Cost Estimate

Parts Cost = Cost of Discard.

From Ref. 5, Table E-1

$$\begin{aligned} \text{Average cost of discard/repair} &= \frac{\sum (\text{Discard Cost } I_{em} \times \lambda)}{\sum (\lambda)} \\ &= \frac{\$98894.1/10^6 \text{ hours}}{215.7 \text{ failures}/10^6 \text{ hours}} \end{aligned}$$

= \$458/failure 1977 \$

= \$555/failure 1979 \$

where: λ = failures/ 10^6 hours

3.2.2 AN/SLQ-32(V)2 R&D Cost Estimate

The research and development costs for the AN/SLQ-32(V)2 were determined as follows:

<u>Item</u>	<u>R&D Cost</u>
AN/SLQ-32	\$26M
AN/SLQ-31	<u>\$23M</u>
Total	\$49M

The item developed was a suite 3 model (ESM and ECM). On the assumption that development of a suite 2 (ESM only) would require approximately two-thirds of this effort, the suite 2 R&D cost would be $\$49M \times 2/3 = \$32.6M$. An additional cost of 5% is estimated for TECHEVAL/OPEVAL testing and modifications. Thus, overall suite 2 estimated R&D cost is \$34M.

Expenditures for the AN/SLQ-31 and 32 took place over approximately a 5-year period. Assuming that the average point of expenditure occurred in 1977, an adjustment can be made to the \$34M figure to reflect 1979 buying power. When this is done (at 10% per year), the amount becomes \$41.1M.

Clearly, there may be an argument for excluding AN/SLQ-31 R&D costs from this estimate. The AN/SLQ-31 cost does not reflect the AN/SLQ-32 hardware, but instead may be interpreted as a management decision to develop two models rather than one. Nevertheless, for the purposes of this analysis it was felt that this cost was intended for the overall program and should be depreciated over the life of this equipment. It may turn out at a later time that effort spent on the AN/SLQ-31 is applied to another equipment's development. In that event, the cost of AN/SLQ-31 should be depreciated over the newly developed hardware.

3.2.3 AN/SLQ-32(V)2 Depot Support Repair Cost Estimate

Normally, the depot support costs are determined from data generated in a level of repair analysis (LORA), such as that performed in the preparation of Ref. 5. That document provides summary data of factory (depot) support costs for a Phase II configuration and Phase III support concept. An average cost for a repair at the depot was determined from the summary data as follows:

From the Technical Support Plan (Ref. 5), paragraph 9.8.3, the estimated labor cost for depot repair is:

Labor \$ = 8 technicians \times 2000 hours/year \times 10 years \times \$11.00/hour = \$1,760,000

From Table 9-2 of Ref. 5, depot repair costs are computed to be \$117,429,000 on the basis:

$$\frac{\text{Labor \$}}{\text{Repair \$}} = \frac{\text{No. of Repairs} \times \text{Labor rate}}{\text{No. of Repairs} \times \text{Repair rate}}$$

$$\text{Repair rate} = \frac{\text{Repair \$} \times \text{Labor rate}}{\text{Labor \$}} = \frac{\$117,429,000 \times 11.00}{1,760,000} = \$733.93 \text{ (1977 \$)}$$

Since no information is available to establish whether or not a significant repair cost differential exists between phase II configuration and the current configuration, none is assumed, and current MTBMA and MTTR values will be used to determine overall cost. On the basis of an assumed inflation rate of 10% per year, the 1979 depot repair cost is,

$$\begin{aligned} \text{Average Depot Repair Cost/repair} &= \$733.93 \times 1.21 \\ &= \$888. \end{aligned}$$

3.2.4 Conceptual ESM Depot Repair Cost Estimate

The hardware represented in the conceptual ESM reliability and cost estimates were derived mainly by selection of current off-the-shelf components. Manufacturers were contacted to determine compliance with performance parameters, availability, cost, reliability, and complexity. The depot maintenance concept is to return high-cost repairable items to either the manufacturer or to establish a Navy depot capable of equivalent cost-effective repair. Since it was felt that the latter would nevertheless be more costly and difficult to project, the costs associated with a manufacturer as a repair depot were determined. Manufacturers were surveyed and requested to provide an estimate of the average cost to repair a particular component to be used in the conceptual design. Only manufacturers of the high-cost "RF components"* were contacted. The results of the survey indicated average cost to repair would be between 20% and 60%. An average of 40% of the procurement cost was chosen for estimating the cost of depot repair material.

3.2.5 AN/WLR-1G and AN/SLQ-32(V)2 Tools and Test Equipment Cost Estimate

Tool and test equipment expenses considered to be applicable to the AN/WLR-1G and AN/SLQ-32(V)2 are shown in Tables 3-1 and 3-2, respectively. The costs to repair test equipment are not included. Built-in test equipment is costed as part of the basic hardware suite. External test equipment is assumed to be shared among many systems; therefore the repair is of trivial prorated cost impact.

3.2.6 Summary of Data Inputs and Numerical Estimates of LCC Elements

Table 3-3 contains the basic cost, failure, repair, and operational data used to make the LCC analyses for the three ESM configurations. These data entries are based on the computational formulas as described in Section 3.1 and the data presented in Section 3.2. Table 3-3 also presents the operating and maintenance costs on a per-mission basis. Line 8 gives the costs of materials used at the organizational, intermediate, and depot maintenance

* Components other than printed circuit boards.

Table 3-1. AN/WLR-1G special-purpose test equipment list.

Category	Equipment	Parameters	Application	Cost
Differential Voltmeter (DC VTVM)	CCUH-801B	0-500 VDC	AN/WLR-1G	\$ 665
RF Signal Generator	CAQI-612A	450-1230 MHz		\$4300
	CAQI-8614A	0.80-24G GHz		\$4750
	CAQI-8616A	1.8-4.5 GHz	AN/WLR-1G TUNERS	\$4750
	CAQI-620B	7.0-11.0 GHz		\$5650
	CAQI-626A	10.0-15.5 GHz		\$8450
	CAQI-628A	15.0-21.0 GHz		\$8450
Radio Test Set	TS-907/UJR	300-1100 MHz	AN/WLR-1G	\$3000 (Est.)
Frequency Meter	CAQI-536A	960-4200 MHz		\$ 990
	CAQI-537A	3700-1230 MHz		\$ 730
Sweep Generator	AN/TRM-3	60 to 160 MHz 20% Deviation	AN/WLR-1G CONVERTERS	\$6000 (Est.)
Sweep Gen Main-Frame Sweep Gen Tuning Unit Sweep Gen Tuning Unit Sweep Gen Tuning Unit Sweep Gen Tuning Unit	HP 8690B			\$3100
	HP 8692B	2-4 GHz		\$4050
	HP 8693B	4-8 GHz	AS-899E,F/SLR ANTENNA	\$3600
	HP 8694A	8-18 GHz	& AN/WLA-3B	\$6000
	HP 8696A	18-26 GHz		\$3500
Standing Wave Indicator	NS 0967-169-1010	3.0-12.0 GHz	AS-899E,F/SLR	\$ 500 (Est.)
Pulse Generator	HP-214B		AN/WLA-3B	\$2500
Recorder	HP 7035B		AN/WLA-3B	\$1600
				\$72,635 TOTAL

NOTES: 1) 1979 prices, no discounts.

2) Prices either estimated or obtained from Hewlett Packard Electronic Instruments and Systems Catalog, 1979.

3) One of each piece required.

SOURCE: AN/WLR-G technical manuals for equipment types.

Table 3-2. AN/SLQ-32(V)2 special test equipment cost.

ONBOARD:

CONTRACT-FURNISHED	\$8,251.66/system 1979
--------------------	------------------------

GOVERNMENT-FURNISHED	\$15,000 est.
----------------------	---------------

Including such items as:

Teletype Terminal

Spectrum Analyzer

Total	<u>\$23,251</u>
-------	-----------------

DEPOT:

Unable to determine a cost figure due to information indicating contractor support not requiring any added outlay for depot test equipment.

levels. The labor costs for all types of maintenance and for operators are listed in line 9. In addition to the three corrective maintenance costs, the table shows the cost of preventive maintenance as a separate item in line 9.1. The total labor cost for shipboard maintenance is given in line 9.4.

The total corrective maintenance, line 9.6, includes all maintenance except preventive. The total maintenance cost in line 9.7 is the sum of the costs for corrective and preventive maintenance per mission. The material costs of line 8 are added to the labor costs of line 9 to obtain the combination of labor and material costs shown in line 10. Failure and repair time information for the AN/WLR-1G, AN/SLQ-32(V)2 and the conceptual design has been taken from Refs. 2 and 3, respectively.

Table 3-3. Basic cost, failure, repair and operational data.

	Conceptual			
	AN/WLR-1G	AN/SLQ-32(V)2	Computer Control and Display	Other Equipment Total
1. Total Mission Man-Hours	720	720	720	720
2. Number of Corrective Actions/Mission	9.606	4.172	1.077	9.223
3. Labor Rates per Hour				
3.1 Operator	12.68	12.68	12.68	12.68
3.2 Organizational Maintenance	12.68	12.68	12.68	12.68
3.3 Intermediate Maintenance	12.68	12.68	12.68	12.68
3.4 Depot Maintenance	28.55	28.55	28.55	28.55
4. Average Maintenance Hours, MTTR				
4.1 Organizational	3.35	1.045	.752	0.40
4.2 Intermediate	—	—	—	1.00
4.3 Depot	—	2.94	2.94	2.94
5. Number of Repairs Per Mission				
5.1 Organization	9.606	4.172	1.077	8.146
5.2 Intermediate	—	—	—	4.406
5.3 Depot	—	4.089(a)	1.077	3.74
6. Average Cost of Material(b) per Repair				
6.1 Organization	411.	555.	129.99	0
6.2 Intermediate	—	—	—	314.79
6.3 Depot	—	804.06	804.06	687.06
7. Labor Hours per Mission				
7.1 Preventive Maintenance	15.	22.5	1.752(c)	15.
7.2 Organizational Maintenance	32.18	4.36	.810	3.258
7.3 Intermediate Maintenance	—	—	—	4.406
7.4 Subtotal	47.18	26.86	2.562	20.912
7.5 Depot Maintenance	—	12.02	2.961	10.996
7.6 Total Maintenance	47.18	38.88	5.399	30.724
7.7 Operator	672.82	693.14	N/A	N/A
				696.526

(a) 98% of all failures repaired at depot

(b) All costs except labor

(c) Preventive Maintenance Prorated by number of failures between "Computer" & "Other Equipments"

(continued)

Table 3-3. Basic cost, failure, repair and operational data (continued).

	AN/WLR-1G	AN/SLQ-32(V)2	Conceptual		
			Computer Control and Display	Other Equipment	Total
8. Cost of Materials ^(d) per Mission					
8.1 Organizational Maintenance	3948.	1143.	140.00	0	140.0
8.2 Intermediate Maintenance	—	—	—	1386.96	1386.96
8.3 Depot Maintenance	—	3288.	809.69	2569.62	3379.31
8.4 Total Materials Cost per Mission	3948.	4431.	949.69	3956.58	4766.27
9. Labor Costs per Mission					
9.1 Preventive Maintenance	190.20	285.30	22.22 ^(e)	167.98 ^(e)	190.20
9.2 Organizational Maintenance	408.04	55.28	10.27	41.31	51.58
9.3 Intermediate Maintenance	—	—	—	55.87	55.87
9.4 Subtotal: Shipboard Maintenance	598.24	340.58	32.49	265.16	297.65
9.5 Depot Maintenance	—	343.17	84.54	313.94	398.47
9.6 Corrective Maintenance	408.04	398.45	94.81	411.12	505.92
9.7 Total Maintenance	598.24	683.75	117.03	579.11	696.12
9.8 Operator	8531.36	8789.02	N/A	N/A	8831.95
10. Labor and Materials Cost per Mission					
10.1 Preventive Maintenance	190.20	285.30	20.64 ^(e)	167.98 ^(e)	190.20
10.2 Organizational Maintenance	4356.04	1198.28	150.27	41.31	191.58
10.3 Intermediate Maintenance	—	—	—	1442.83	1442.83
10.4 Subtotal: Shipboard Maintenance	4546.24	1483.58	170.91	1652.12	1823.03
10.5 Depot Maintenance	—	3631.17	894.23	2883.56	3777.79
10.6 Corrective Maintenance	4356.04	4829.45	1044.50	4367.70	5412.20
10.7 Total Maintenance	4546.24	5114.75	1065.14	4535.68	5600.82
10.8 Operator	8531.36	8789.02	N/A	N/A	8831.95

(d) All costs except labor

(e) Preventive maintenance prorated by number of failures between "Computer" & "Other Equipment"

4.0 DISCUSSION OF RESULTS

Table 4-1 summarizes the LCC estimates for the three ESM configurations. The tabular entries show estimates of the selected cost elements over the time span extending from the definition of the system design concept through research and development, the production of 100 systems, and the operation and maintenance of a typical system over a 10-year service life. In order to show the relative importance of each cost element, Table 4-1 also lists the percentage which each element contributes to the total LCC of the ESM configuration. The LCC summary for the AN/WLR-1G configuration is primarily of historical interest, and therefore most of the discussion will focus on relative differences in costs between the AN/SLQ-32 and the NOSC conceptual ESM design.

4.1 DISCUSSION OF LCC CATEGORIES

Before discussing the numbers in Table 4-1, it is perhaps helpful to review the meanings of the listed cost categories.

4.1.1 Research and Development Costs

For purposes of this LCC analysis, a production run of 100 systems is assumed, and the total R&D cost is spread equally over the 100 systems produced. R&D costs include OPEVAL and TECHEVAL costs.

4.1.2 Procurement Cost

The procurement cost per operational system is the estimated production cost, i.e., what the Navy has to pay for each system installed at a user location.

4.1.3 Initial Spares Cost

"Initial spares" refers to the spare parts and assemblies which must be placed on board ship with each operational ESM system.

4.1.4 Tools and Test Equipment

Tools and test equipment includes all items that must be provided with each operational system and that would not be on board if there were no ESM system.

4.1.5 Operating and Maintenance Cost

The 10-year operating and maintenance costs are generated directly for the corresponding cost elements in Table 3-3. The costs in Table 3-3 are on a per-mission basis. Over the 10-year service life, each system will perform 60 missions. Therefore the 10-year service life operating and maintenance costs are merely 60 times the single-mission cost.

The subtotals and totals in the table are explained by the titles. Although the NOSC conceptual ESM design and the AN/SLQ-32(V)2 are of approximately similar complexity, their total LCCs are quite different, \$2,917.00 for the NOSC conceptual design and \$2,149,000 for the AN/SLQ-32. The operating and maintenance costs for the two configurations are almost the same. The difference between their LCC estimates is due almost

Table 4-1. Summary of life cycle costs per system for three ESM configurations.
(Cost in thousands of 1979 dollars)

Acquisition Costs Prorated for a Production of 100	AN/WLR-1G		Per System Costs & % AN/SLQ-32(V)2		Conceptual	
	Cost	%	Costs	%	Costs	%
1. Research and Development						
2. Procurement	30*	.543	411	19.125	36	1.234
3. Initial Spares	220.	19.910	799	37.180	1,406	48.2
4. Tools and Test Equipment	22.	1.991	80	3.723	593	20.33
5. Total Acquisition Costs (sum of lines 1 through 4)	73	6.606	25	1.163	25	.857
	345	29.050	1,315	61.191	2,060	70.621
6. Operator Personnel	512	46.335	527	24.523	530	18.169
7. Corrective Maintenance Labor	24	2.172	24	1.117	30	1.028
8. Corrective Maintenance Material	237	21.448	266	12.378	286	9.805
9. Total Corrective Maintenance (sum of lines 7 and 8)	261	23.620	290	13.495	316	10.833
10. Preventive Maintenance	11	.995	17	0.791	11	.377
11. Total Maintenance (sum of lines 9 and 10)	272	24.615	307	14.286	327	11.21
12. Total Operating and Maintenance Costs (sum of lines 6 and 11)	784	70.950	834	38.809	857	29.379
13. Total 10-Year LCC (sum of lines 5 and 12)	1,129	100.00	2,149	100.00	2,917	100.00

* Data not available. Estimate based on past experience.

entirely to elements in their acquisition costs. These costs in thousands of 1979 dollars are summarized below. The differences shown are costs for the conceptual design minus costs for the AN/SLQ-32.

	<u>AN/SLQ-32</u>	<u>Conceptual</u>	<u>Difference</u>
Research and Development	411	36	-375
Procurement Cost per Operational System	799	1,406	607
Initial Spares	80	593	513
Tools and Test Equipment	<u>25</u>	<u>25</u>	<u>0</u>
Acquisition Cost	1,315	2,060	745

Because of the similarity in the technology used in the designs of the two configurations, the estimated costs for tools and test equipment are the same. The cost differential arises entirely from the costs for the other acquisition cost elements.

The R&D cost for the AN/SLQ-32 was much higher than that projected for the NOSC conceptual design. This higher R&D cost for the AN/SLQ-32 reflects two facts. At the time of its development, the AN/SLQ-32 represented a major advance in the state-of-the-art. By contrast, it is estimated that the planned conceptual ESM configuration represents only a limited advance. Even more significant is the fact that the Navy elected to sponsor two parallel development programs in the case of the AN/SLQ-32. (The alternate program was the AN/SLQ-31, which was rejected in favor of the AN/SLQ-32.) Thus, in large measure, the AN/SLQ-32 research and development cost reflects such costs for two programs.

In reviewing the R&D costs, it is appropriate to make the following observation. The Navy currently has the option of retiring all ESM systems in the fleet and replacing them with new copies of the AN/SLQ-32 configuration or of starting research and development and production of a new "conceptual" configuration. To compare these two alternatives, only future costs should be considered, since these are the only ones that can be changed. Accordingly one would delete the R&D costs for the AN/SLQ-32(V). This would give a projected 10-year LCC of $\$2,078,000 - \$411,000 = \$1,667,000$ for the AN/SLQ-32. The 10-year LCC cost for the NOSC conceptual ESM design must still include the R&D cost of \$36,000, leaving an estimated LCC of \$2,917,000 per operational conceptual system.

The higher R&D costs for the AN/SLQ-32 are more than offset by the higher costs of the conceptual ESM design for procurement and initial spares. These higher procurement costs reflect the increased expense of non-microwave integrated circuits (MIC) off-the-shelf components in the conceptual design. Overall costs should be reduced in proportion to the number of MICs developed.

The differences in initial spares costs between the two systems also reflect differences in maintenance philosophies. For the AN/SLQ-32, failed assemblies are removed at the organizational maintenance level and an estimated 98 percent are sent to depot for repair. There is no intermediate level of maintenance. By contrast, the NOSC conceptual ESM design uses replaceable modular elements with a large degree of discard in lieu of repair. A significant portion of the maintenance is performed on board ship at the intermediate maintenance level,

and this is reflected in less depot maintenance. The heavier shipboard maintenance load for the NOSC conceptual ESM design generates the requirement for a higher cost of spares when compared with the AN/SLQ-32.

The remaining cost elements in the LCC analyses indicate no striking differences between the AN/SLQ-32 and the NOSC conceptual ESM design. It is significant that the maintenance costs of the two configurations are not very different in view of the fact that the conceptual ESM is somewhat more complex in function than the AN/SLQ-32 and, accordingly, offers performance features for long-range surveillance as well as antiship-missile defense. It is also significant that maintenance is not a large contributor to total LCC for either configuration. The maintenance cost for the 10-year service life for the AN/SLQ-32 is \$307,000 and for the conceptual design is \$347,000. These costs represent only 14.3 and 11.9% of the total LCC for the two configurations, respectively.

5.0 RECOMMENDATIONS

It would be inappropriate in this report to attempt to evaluate whether the estimated LCCs are unacceptably high. That evaluation must be made by the Navy and based on trade-offs between the costs and the military requirement for the information provided by each ESM system. It is perhaps appropriate, however, to suggest how future LCC analyses might provide more precise cost information. It is also useful to point out how the present analysis can be used to suggest cost-reducing trade-off possibilities. The following recommendations are submitted:

1. A centralized DoD or Navy LCC data base should be generated from user and other experience to allow timely and accurate LCC comparisons between proposed and existing systems. Such data are now fragmented or nonexistent.
2. Alternative maintenance philosophies should be considered for possible LCC reductions of the conceptual design. Approaches such as shipboard module repair and elimination or reduction of throw-away modules are examples.
3. Design alternatives should be identified and evaluated in terms of performance and cost trade-offs to determine the limiting factors involved in a conceptual ESM system development program.
4. Development effort for the conceptual ESM should include an appraisal of the number of MICs that can, within the current state-of-the-art, be incorporated in the design and the consequent potential for cost savings. The MICs proposed here entail the integration of several functions into a single package.

6.0 REFERENCES

1. Factors, Formulas and Structures for Life Cycle Costing, Mary Earles, Earles-Eddins, 1978.
2. Report on Availability Study of the AN/WLR-1G and AN/SLQ(V)2 ESM Systems, NOSC TR 425, February 1979.
3. Report on Availability Study of a Conceptual ESM, Prepared by Evaluation Research Corporation, CDRL A002 under Contract N66001-78-C-031.
4. Reference available to qualified requesters.
5. Design to Price Electronic Warfare Suite, Volume I – System Technical Data, Technical Support Plan for AN/SLQ-32(V1), AN/SLQ-32(V2), AN/SLQ-32(V3), Raytheon Company, Document No. 061290133-3, 1 May 1976.

LMED
-8